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Microbial bioreduction of antimony and Fe(III) oxyhydroxide in mine tailing soils

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Antimony (Sb) is a highly toxic metalloid of growing environmental concerns, predominantly existing in trivalent and pentavalent forms in natural soils. Antimony is often strongly adsorbed to iron(III) oxyhydroxides, such as ferrihydrite. Microbe-mineral interactions play important roles in the transformations of both Sb and Fe, contributing to the geochemical cycling of Sb. We recently enriched a microbial consortium from stibnite (Sb_2S_3) mine tailing soil, dominated by *Desulfitobacterium* sp., which demonstrated the ability to reduce Sb(V) (1mM). To further understand the biotransformation pathways influencing Sb behavior in natural systems, we investigated the functional capabilities of this Sb(V)-reducing consortium. In addition to Sb(V), the consortium showed anaerobic reduction capabilities for As(V) (1 mM), AQDS (1 mM), Fe(III) citrate (1 mM), and ferrihydrite (24 g/L) in the presence of lactate. Reduction of ferrihydrite resulted in goethite precipitation and remained unaffected by the presence or absence of humic acid (0.15 g/L), suggesting potential direct reduction through an extracellular electron transfer system. Our consortium differs from the previously reported Fe(III)-reducing *Desulfitobacterium metallireducens*, which lacked the ability to directly reduce ferrihydrite [1] or Sb(V). Genomic analysis indicated that approximately 80% of the consortium's sequences belonged to the dominant *Desulfitobacterium* species, containing a recently identified antimonate reductase (AnrA) gene [2]. This dominant *Desulfitobacterium* sp. was successfully isolated and exhibited reduction capabilities for Sb(V), As(V), Se(VI), Se(IV), and Fe(III) citrate. However, ferrihydrite reduction was observed only in co-culture with another consortium isolate, *Lysinibacillus* sp., which lacked metal-reducing activity. Microbial reduction of Fe(III) oxyhydroxides could facilitate the release of the adsorbed toxic metalloids. When reducing Sb(V)-bearing ferrihydrite (0.5% Sb(V)/Fe(III) molar ratio), Fe(II) production was evident, while Sb(V) reduction was absent, suggesting potential extracellular electron transfer mechanism through interspecies interactions facilitating ferrihydrite reduction without Sb(V) metabolism. Overall, our findings illuminate the functional versatility of metalloid-transforming bacteria and emphasize the potential role of indigenous microbiota in mine tailing soils in influencing the geochemistry of toxic metalloids both directly and indirectly.

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